ONBOARD EXPERIMENT DATA SUPPORT FACILITY (OEDSF)

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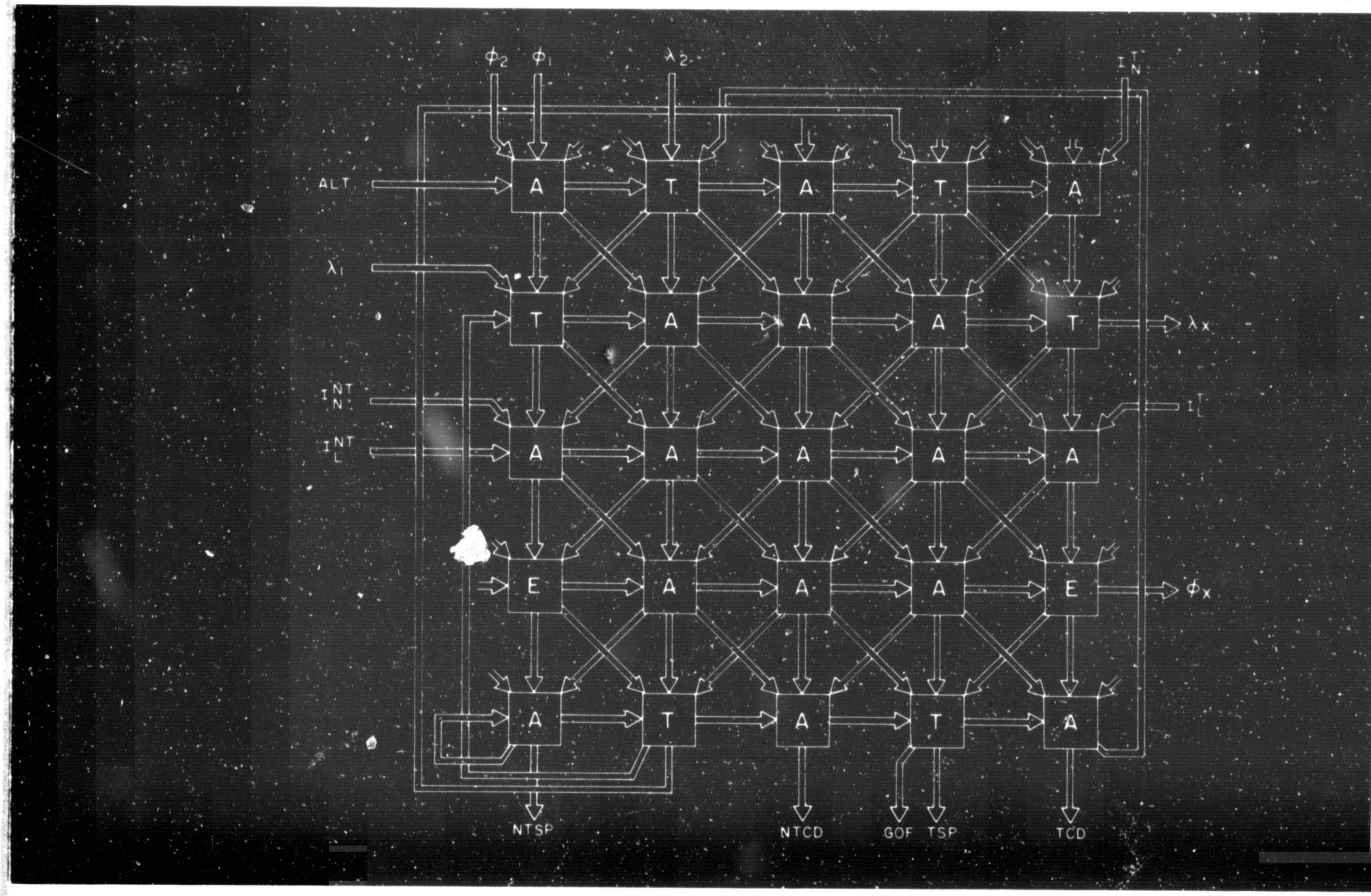
CONCEPTUAL DESIGN STUDY



EXECUTIVE SUMMARY

GENERAL ELECTRIC

PREFACE

The traditional approach to processing data from spaceborne sensors in ground facilities has proven inadequate to satisfy even today's requirements in terms of quantity, quality, and timeliness. The data received on the ground is raw; it must undergo various processes to render it useable to the experimenter. These range from simple reformatting to complex domain transformation and information extraction processes which are usually accompanied by correlations with time, ephemerides, and other ancillary data which are resident in exogeneous sources. Data is collected rapidly and simultaneously by many sensors but must wait in line to be processed by centers characterized by limited throughput and high cost.

The Space Shuttle can accommodate 10,000 cubic feet of experiments. It will fly, on the average, twenty-five times per year in the 1980's, and technology will have increased many fold the experimenter's capability to generate data. The magnitude of the data processing requirements in the Shuttle Era will far exceed the capabilities of any conceivable system designed and operated using today's methods. We need a new approach.

This approach must creatively exploit the same advanced technology used by those who generate data. The large capacity of the Shuttle, which can cause the data avalanche, also offers the capability to install a significant portion of a new type of end-to-end processing system onboard, permitting the use of this technology to process data in totally new ways at the data source. The purpose of the OEDSF Study was to develop the concept and evaluate the effectiveness of this onboard processor.

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SEPTEMBER 1976

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(OEDSF)

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NATIONAL AERONAUTICS AND SPACE ADMINISTRATION
LYNDON B. JOHNSON SPACE CENTER
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By

GENERAL ELECTRIC
SPACE DIVISION
VALLEY FORGE, PENNSYLVANIA

INTRODUCTION

The OEDSF is an inflight data processor based on a totally new architecture specifically developed to cost-effectively process the data of Shuttle payloads sensors.

Processing data onboard fills the following needs:

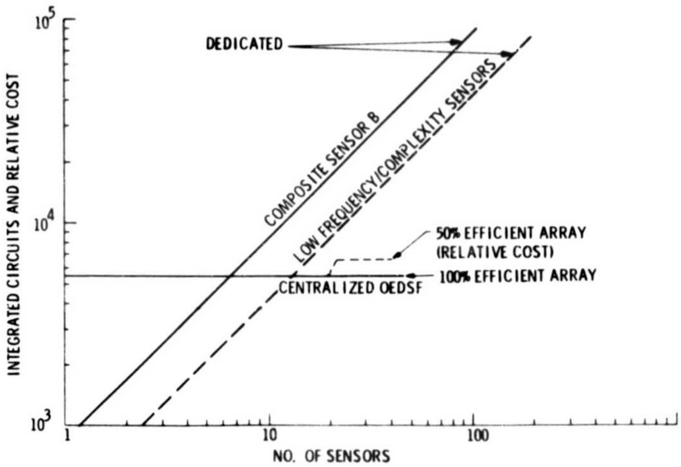
- Reduction of data bulk by conversion to information
- Quick-look for evaluation, interactive operation, etc.
- Real-time computation of engineering representation of sensed phenomena. For example: Value of backscatter coefficient (σo) of a scatterometer as a function of latitude and longitude
- Exploitation of the real-time availability of ancillary data, thereby obviating the need for time-tagging, recording, and recorrelation
- Providing data or information immediately usable by the experimenter or user.

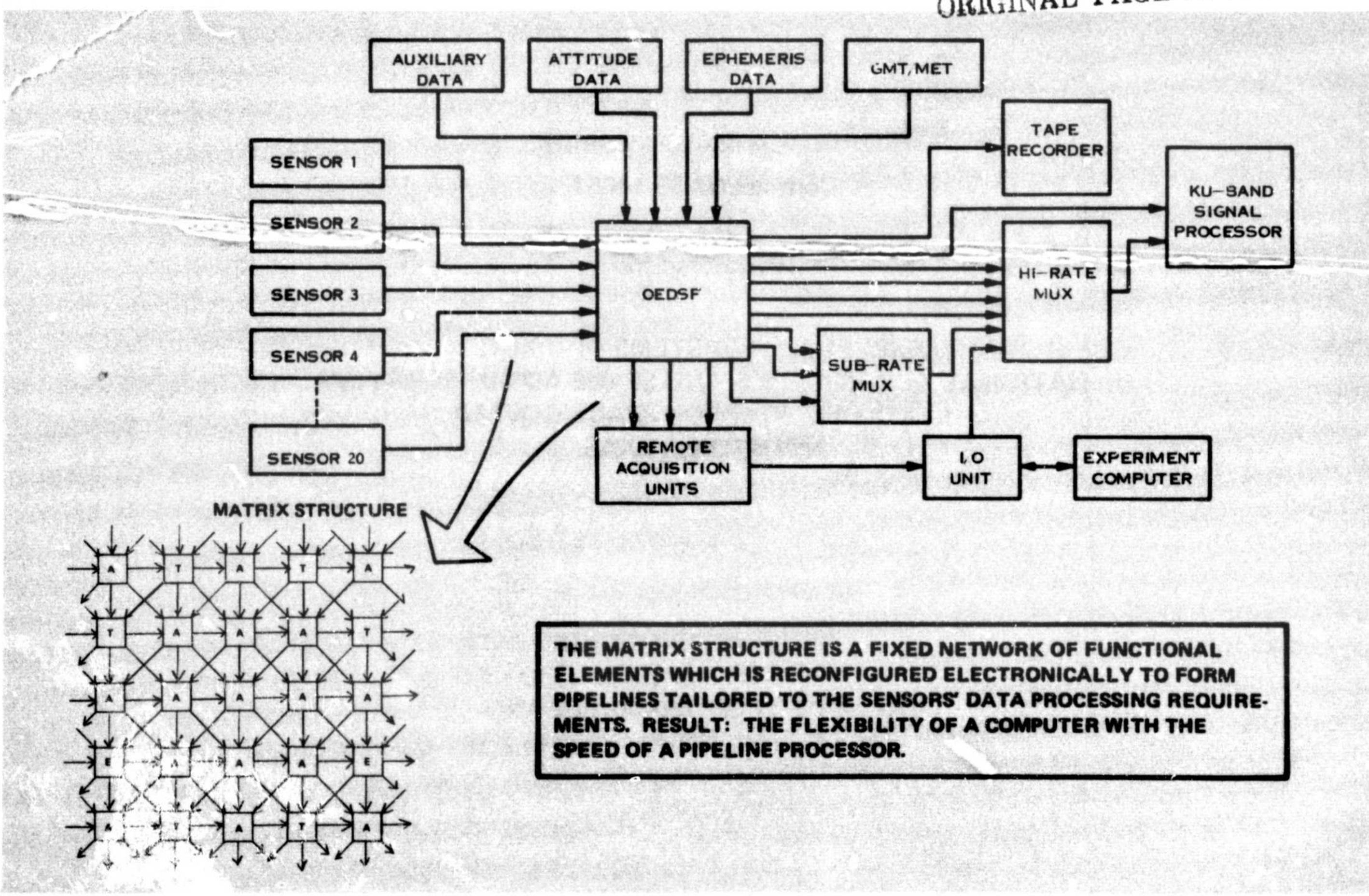
The OEDSF is made up of modular and cascadable matrix processors. Each matrix has been sized to process the data of a full typical shuttle payload.

In general, the use of a shared data processing facility is cost-effective, compared to smaller dedicated processors, when the number of sensors serviced exceeds 8 to 10.

Cost analyses indicate that significant savings are realized by processing data with the OEDSF compared with conventional ground facilities.

The OEDSF embodies growth potential in that it is a strong candidate for implementation with Large Scale Integration (LSI) circuits. This implementation is particularly attractive because it will reduce the cost of production OEDSF's to the point where dedication of an entire matrix to each sensor will be economical.





SUMMARY OF CONCLUSIONS

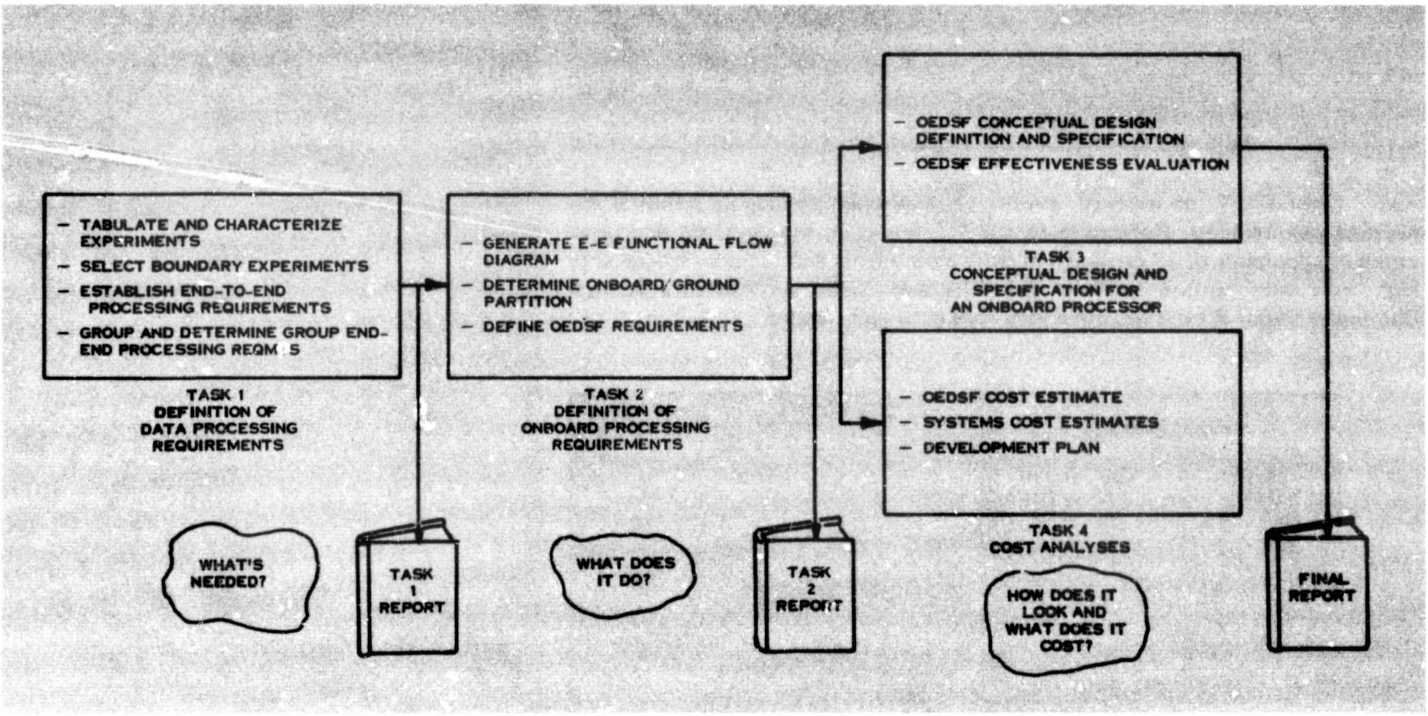
- There are significant benefits to be derived from onboard processing. These include:
  - Timely availability of data to user
  - Lower costs compared to conventional processing approaches
  - Real-time utilization of ancillary information
  - Reduction in the quantity of data transmitted and stored.
- The concept of a processor based on a set of programmable pipeline processors responds to all the requirements of a data processor onboard the shuttle. These include:
  - Cost-effectivity
  - Multiple sensor complements from multiple disciplines
  - Combinations of very low and very high data rates
  - Real-time processing
- The level and extent of processing performed onboard that is beneficial or desired by the user is dependent on the class of user. Most, however, want, and benefit from performing those processes which use ancillary data.

APPROACH

The study was organized to develop and evaluate a conceptual design for a Shuttle onboard data processing facility based on the requirements of shuttle payload instruments.

The study was anchored to a point design approach; i.e., designing to satisfy specific requirements, then broadening those requirements to encompass a more general set. The specific requirements were derived from "boundary" experiments: A limited set of sensors selected because they are either representative of many, or they impose demands of such magnitude that their resolution will also satisfy the demands of many sensors whose requirements fall within the envelope defined by the boundary experiments.

The study was divided into four tasks which formed a logical flow beginning with an analysis of sensors and their processing requirements and culminating in the design of a processor satisfying these requirements onboard in a cost-effective approach. Cost analyses and a development plan were also generated.



SENSOR PROCESSING REQUIREMENTS

A set of over 150 instruments was culled to select 77 experiments which are candidates for flight on the Shuttle. A limited set of these experiments were selected as "boundary" experiments because they satisfied the selection criteria which imposed "tall-pole" and "representativeness" conditions on the data processing requirements. The processing requirements for these selected boundary experiments were then defined.

Six sensors were originally selected as the "boundary" sensors which were to provide "point design" requirements.

The full end-to-end processing requirements for four of these sensors were developed, and complete functional flow diagrams converting the required processes to real-time processes were generated. These four sensors cover the spectrum of data rate and processing complexity.

- Advanced Technology Scanner (ATS)
  - Infrared Spectrometer (IRS)
    - Radiometer Scatterometer (RADSCAT)
      - Correlation Interferometer for the Measurement of Atmospheric Trace Species (CIMATS)

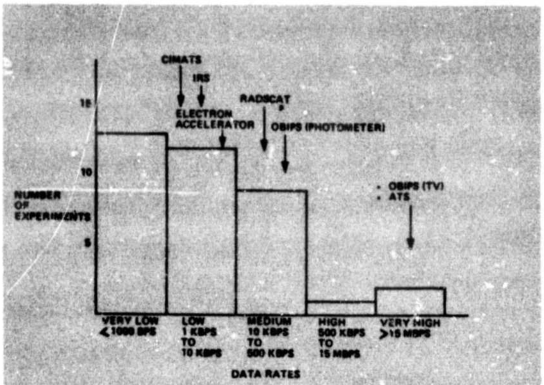
- ONBOARD PROCESSES SATISFY ALL USERS
- ONBOARD PROCESSING IN REAL-TIME
- NO LARGE QUANTITIES OF PRE-STORED DATA ONBOARD
- NO FREQUENT UPDATE OF ONBOARD PRE-STORED DATA
- NO GROUND REPEAT OF ONBOARD PROCESSES
- ONBOARD PROCESSES WELL DEFINED AND STABLE
- CLEAN INTERFACE TO GROUND PROCESSING

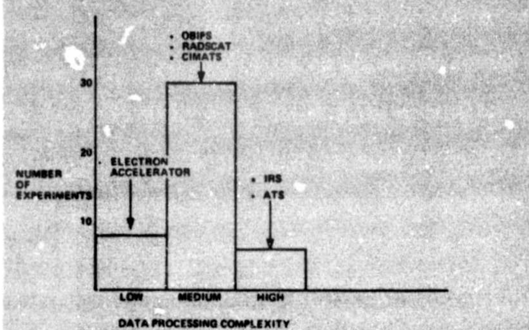
The location of partitions between onboard and ground processing were based on a set of seven criteria and the processes selected to be performed onboard for each sensor were decomposed into the fundamental functions: Arithmetic, Trigonometric, and Exponential/logarithmic. This exercise was performed iteratively with the definition of the OEDSF architecture and the concept design of the processing elements which determined the processing level capability of the OEDSF elements.

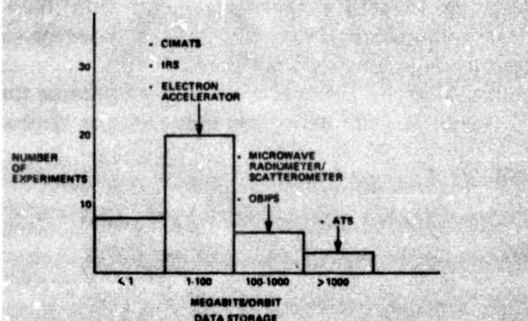
SENSOR	PROCESSES/CHANNEL ARITH	TRIG	LOG/EXP	FREQUENCY IN BPS TOTAL	CHANNEL	CHANNELS	WORD SIZE	DATA BASE (BITS)
ATS	82	15	1	120×10^6	1×10^6	120	8 BITS	100K
RAD/SCAT	213	67	0	15×10^3	15×10^3	1	10 BITS	10K
IRS	131	0	4	3.3×10^3	1.99×10^2	17	18 BITS	250K
CIMATS	31	19	0	2.904×10^3	2.904×10^2	10	12 BITS	170K

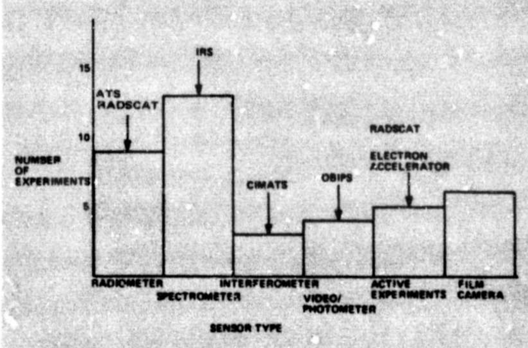
Two "Composite" (or average) sensors were defined to enable defining full payload requirements. Composite sensor A is based on the data rate and processing requirements of 77 candidate shuttle instruments and includes several very high data rate sensors such as the ATS and Synthetic Aperture Radars. Composite sensor B excludes these very high data rate sensors.

PARAMETER	COMPOSITE SENSOR A	COMPOSITE SENSOR B
FREQUENCY	3.0 MBPS	190 KBPS
ARITHMETIC PROCESSES (PER WORD)	1250	1160
TRIGONOMETRIC PROCESSES (PER WORD)	288	250
EXPONENTIAL PROCESSES (PER WORD)	36	40
NUMBER OF CHANNELS	18	10
WORD SIZE (BITS)	12	12
BUFFER SIZE REQUIRED (BITS)	84K	93K
MEMORY SIZE REQUIRED (BITS)	118K	131K









OEDSF REQUIREMENTS

The requirements were derived from the onboard segment of the functional flow diagrams. The boundary sensors, by definition, establish both the spectrum extremes for signal characteristics and the extremes of the processing complexity.

The OEDSF must handle many experiments from several disciplines, thus the processing requirements established by the boundary sensors were generalized, and the processing capability of the OEDSF derived from these requirements was implemented with sufficient flexibility to perform more than these processes.

The required processing functions tabulated on the flow diagrams were extracted and converted to an implementation process. Algorithms were then developed to perform this process. The steps of the algorithms were grouped as the set of functions required. All required processes can be performed by the functions tabulated.

1. TRIGNOMETRIC FUNCTIONS

a. Sine
b. Cosine
c. Tangent
d. Cotangent
e. Secant
f. Cosecant
g. Inverse Sine
h. Inverse Cosine
i. Inverse Tangent

2. EXPONENTIAL FUNCTIONS

a. Exponential
b. Natural Logarithm

3. ALGEBRAIC FUNCTIONS

a. Algebraic addition with accumulation capability
b. Signed multiplication with reciprocal input capability

4. CONTROL FUNCTIONS

a. Multiplexing
b. Demultiplexing
c. Storage and Retrieval
d. Counting
e. Delay

ARCHITECTURE OF THE OEDSF

By definition, architecture is the art or science that pertains to the method or style in which some physical structure is built. In electronic signal processing, architecture is more explicitly defined as the method of establishing the inter-signal relationship with respect to the processes or transfer functions comprising the system. At the system level, architecture defines the processing philosophy and dimensional distribution. Processing structures are further characterized as functions of time.

The specific requirements of onboard processing generated a totally new set of characteristics needed by the processor.

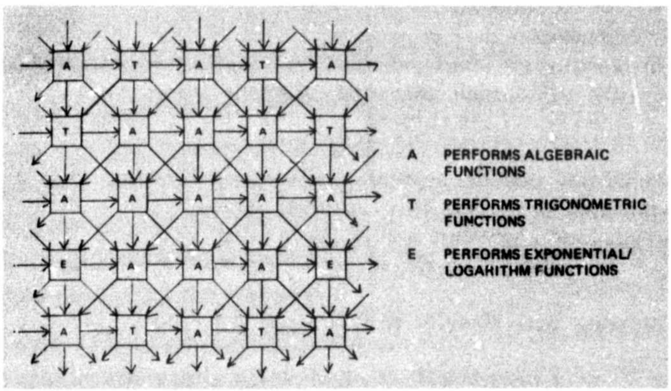
- Multiple Experiments
- High Data Rates
- Real Time Processing
- Flexible Configurations
- Physical Characteristics
- User Orientation
- Spaceflight Qualification
- Growth Potential

The array (or matrix) architecture defined here was invented during this study to combine the advantageous aspects of the three basic architectures evaluated: Small Computer, Serial, and Pipeline.

EVALUATION CRITERIA	SMALL COMPUTER	SERIAL	PIPELINE	ARRAY
MULTIPLE SENSORS I/O CAPABILITY	POOR	POOR	POOR	EXCELLENT
OPERATIONAL SPEED	POOR	FAIR	EXCELLENT	EXCELLENT
FLEXIBILITY OF PROCESSING	EXCELLENT	GOOD	POOR	EXCELLENT
GATE UTILIZATION EFFICIENCY	POOR	POOR	EXCELLENT	GOOD
REAL TIME CAPABILITY	POOR	FAIR	EXCELLENT	EXCELLENT
IMPLEMENTATION OF COMPLEX ALGORITHMS	EXCELLENT	GOOD	GOOD	GOOD
USER ORIENTATION	EXCELLENT	FAIR	FAIR	EXCELLENT
ADAPTABILITY TO FLIGHT ENVIRONMENT	GOOD	GOOD	GOOD	GOOD
GROWTH POTENTIAL	GOOD	FAIR	EXCELLENT	EXCELLENT

A pipeline approach is required by the high speed real-time processing requirements; however, the high flexibility of a computer is needed to satisfy the simultaneous processing of several instruments, and the changes in instrument configurations.

The concept of a fixed network which can be reconfigured electronically to form arbitrary pipelines responds to the requirements. The particular configuration developed is shown below.



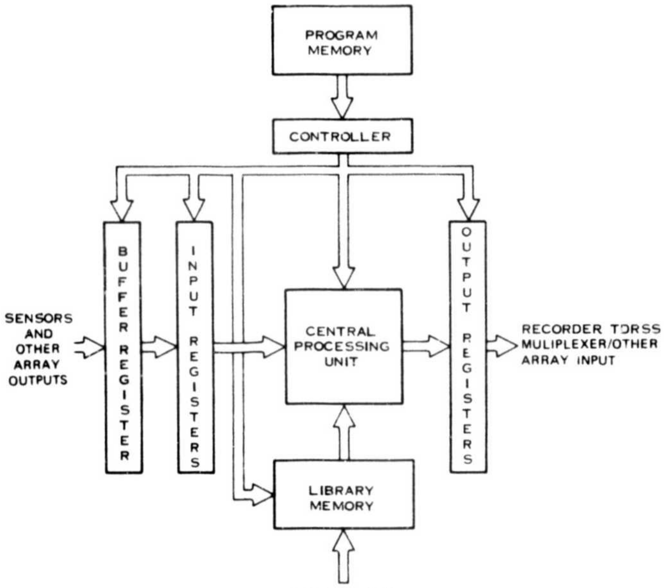
Each element performs its assigned function in 250 nanoseconds. The matrix can be configured in any aspect ratio and with any number of elements. A 5 x 5 element matrix with the distribution shown was selected as a solution to the challenge of processing simultaneously up to 20 sensors with the average data rates and processing complexity attributed to composite sensor B. These calculations assume a 50% programming efficiency; i.e., on the average only one half of the matrix elements are used during any machine cycle.

• 20 SENSORS AVERAGE PER ARRAY	• SIX POINT ARCHITECTURE
• REAL TIME PROCESSING	• 5 X 5 MATRIX CPU
• ASYNCHRONOUS INPUT/OUTPUT	• HIEARCHICAL MEMORY STRUCTURE
• 250 NANOSECOND MACHINE CYCLE	• CENTRAL LIBRARY
• 28,494 AVAILABLE PIPELINES	• THREE GENERIC PROCESSING ELEMENTS
• 100 MEGA FUNCTIONS PER SECOND	• PROGRAMMABLE PIPELINES
• MODULAR AND CASCADABLE	• WIDE BANDWIDTH

DESIGN CONCEPTS

The OEDSF is a data processing oriented, distributed machine characterized by sets of programmable pipeline processors. The distributed architecture derives from the allocation of discrete elements to the performance of dedicated functions. It is a central facility in that it is simultaneously shared by many instruments.

The OEDSF is modular by addition of matrix structures. Each matrix is a programmable processor.



Its components do not necessarily exist as separate entities. For example, the input and output structure is spread throughout the CPU such that each element incorporates self-contained inputs and outputs.

The OEDSF operates asynchronously with the instrument data input and its output. This capability derives from its input/output buffer structure and its speed which, in general, allows several OEDSF CPU cycles for each instrument input word.

The Data Base Memory structure and the Program Memory structure (the control element) have identical architectures based on a hierarchical structure which allows both a high volume and high rates.

The design of each element was derived from major trade-offs in several areas including its implementation in hardwired logic, firmware, or software.

The criteria utilized in the design trade-offs were:

- Design Complexity
- Flexibility
- Preprocessing Requirements
- Power
- Frequency
- Physical Size
- Weight

ARITHMETIC ELEMENT

The basic Arithmetic Processing Element is implemented as a special purpose hardwired design. It solves the general function $\Sigma xy + z$ and all its subsets. It is composed of three distinct functions:

- Multiplier/Divider
- Adder/Subtractor
- Accumulator

The division capability is accomplished by a reciprocal multiplication. This technique computes the reciprocal of the input variable by means of a table. The table possesses a scale factor for the multiplication. Further, a binary scale factor utilized enables the correct quotient to be obtained without shifting.

TRIGONOMETRIC ELEMENT

The basic Trigonometric Element is implemented as a firmware design. It is composed of three distinct parts:

- Quadrant Analyzer
- Argument Tables
- Divider

The quadrant analyzer normalizes the input variables to the first quadrant but retains the input quadrant data. The input argument may be expressed in degrees, radians, or decimal degrees. The inverse parameter is a binary number. The argument table provides the first level of conversion required. The divider manipulates these arguments to generate the desired functions. The significant feature of this approach is the firmware divider. This function minimizes the need for tables and is economic for large arguments. Although the firmware solution requires large memories, current technology renders this approach totally feasible.

EXPONENTIAL ELEMENT

The basic Exponential Element is implemented as a firmware design. It is composed of two distinct parts:

- Logarithm Generator
- Exponential Generator

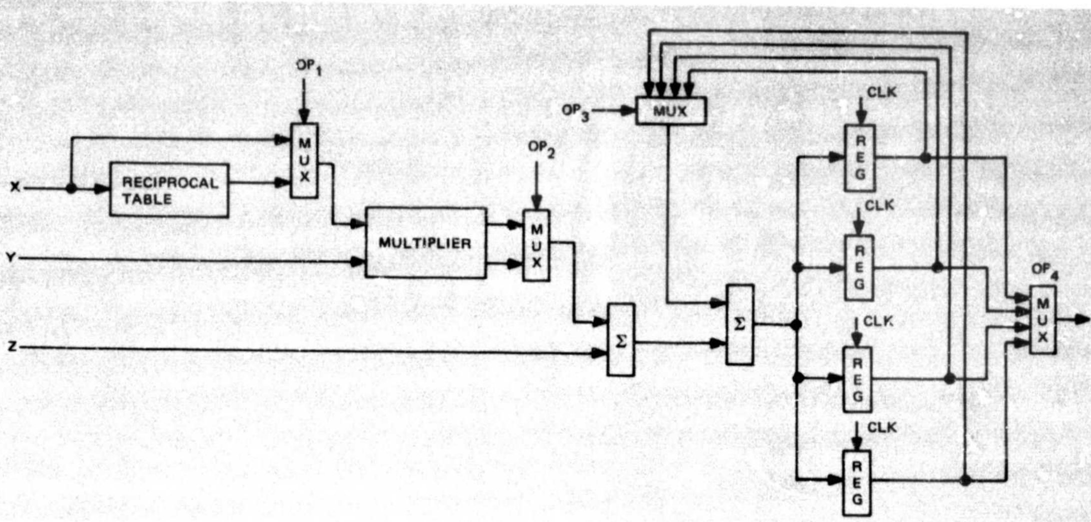
The stored values are based on natural logarithms, i.e., e^z and $\ln z$, but the use of multipliers and dividers provides an overall capability for solving the more general functions X^Y and $\log_X Y$ by using the identities:

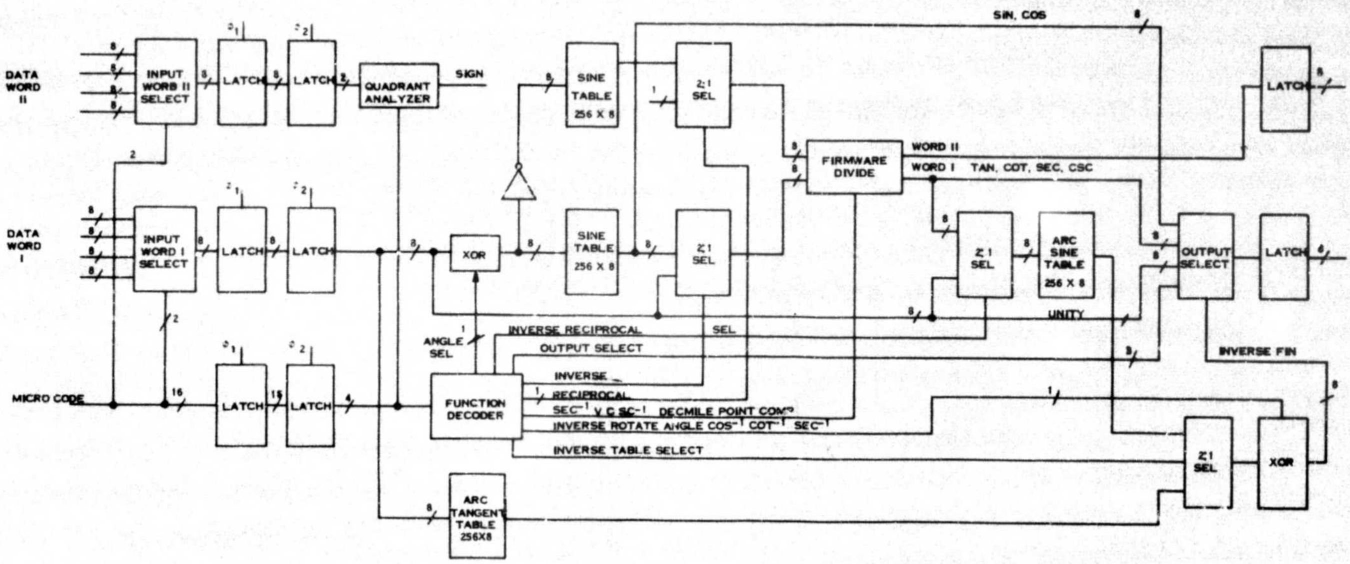
$$X^Y = \epsilon^{Y \ln X}$$

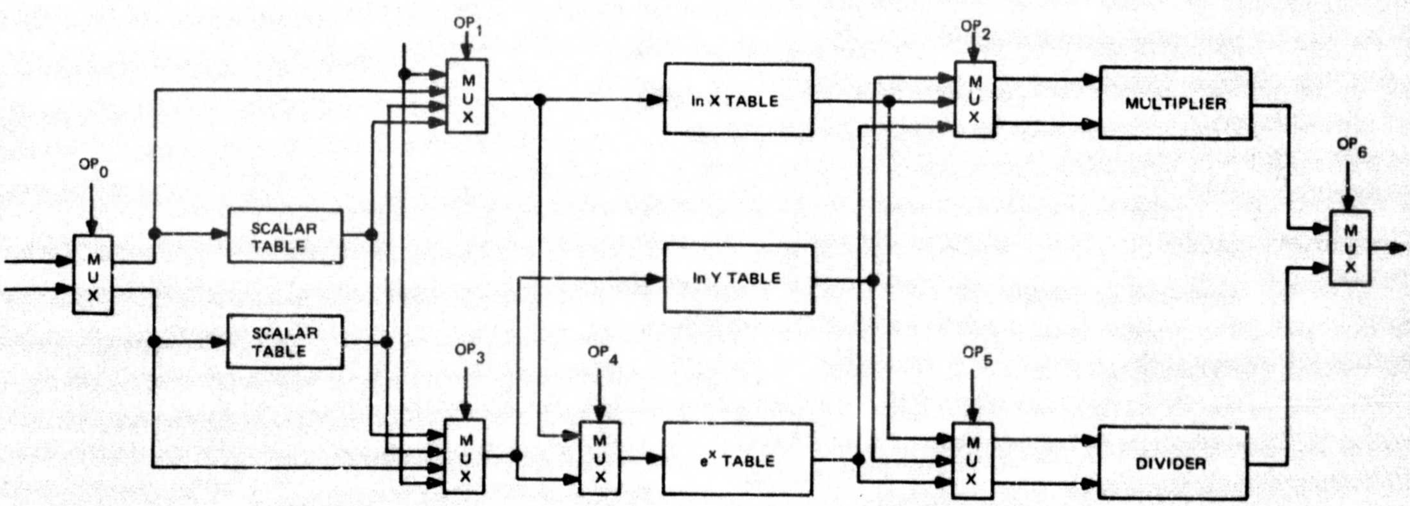
and

$$\log_X Y = \frac{\ln Y}{\ln X}$$

CENTRAL PROCESSING UNIT







INPUT/OUTPUT STRUCTURE

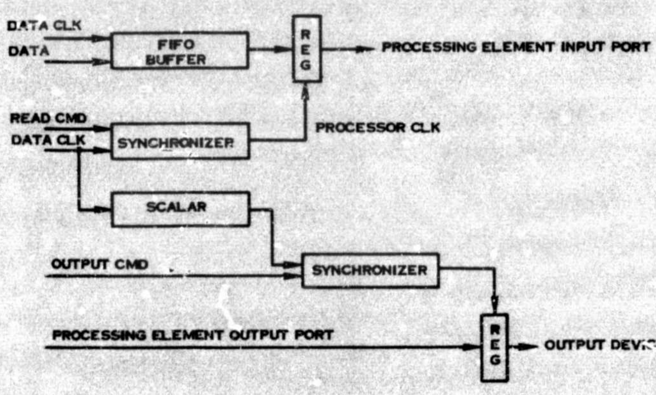
The Onboard Experiment Data Support Facility must be capable of interfacing with a wide range of sensors. These sensors vary in design, mission, and frequency of operation and are normally asynchronous on a sensor-to-sensor basis. In addition, the output data must be synchronized to the input data rate to maintain a continuous data flow. In those processes which perform information extraction, the output data rate is reduced from the input data rate and is a synchronous sub-multiple of it (determined by a Scalar).

The input structure is composed of three major components:

- FIFO Buffer
  - Register
    - Synchronizer

The output structure is composed of three major components:

- Scalar
  - Register
    - Synchronizer

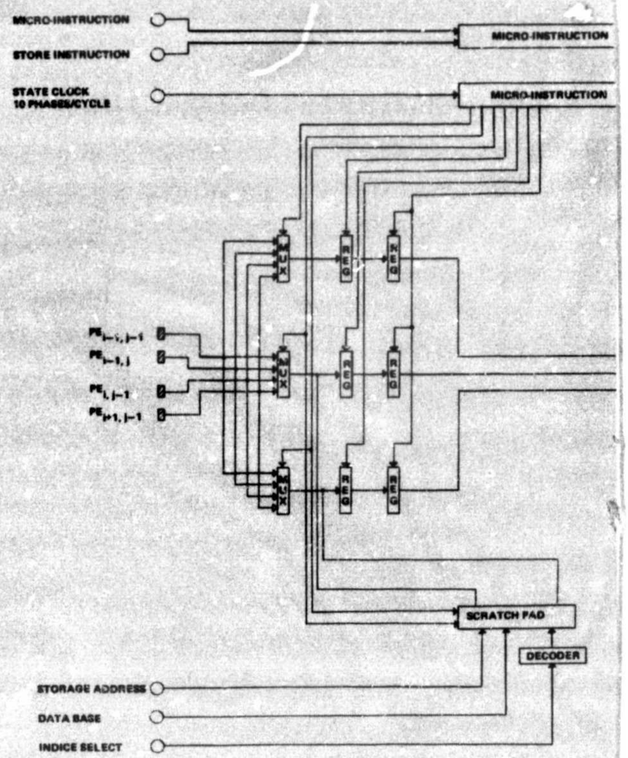


The synchronizers detect the presence of a sensor data word or processed variable that is to be either received or transmitted. The input synchronizer sets a flag on the leading edge of the sensor data clock.

The matrix provides a read command to the required port synchronously with the matrix clock. The logical product of these parameters allows a word to be clocked into the matrix register. The output synchronizer operates in an identical manner except that the flag is set by the logical product of the matrix clock and the output ready command. The data is strobed into the register. In each case, the flag is reset by the active clock. The matrix clock is the active clock for the input and the scaled sensor data clock is the active clock for the output.

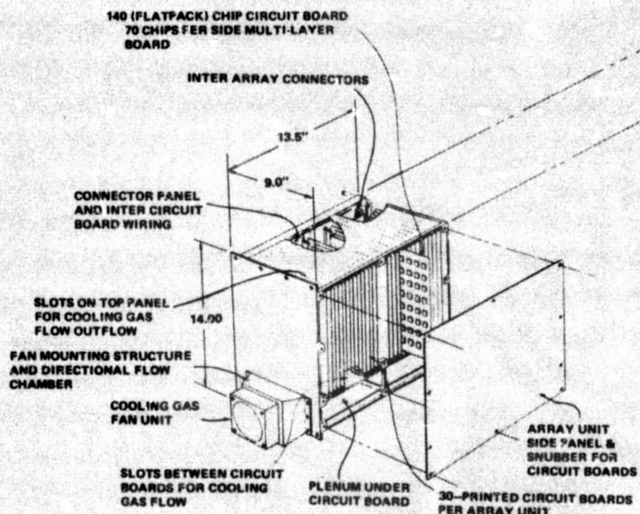
The FIFO buffer provides the data delay required in the processing of the data of certain sensors. Each sensor imposes a different delay requirement ranging from no delay to several milliseconds. Consequently, a modular buffer is incorporated at each input port. The asynchronous nature of First In/First Out memories enhances the OEDSF-to-Sensor interface.

BUS AND CONTROL STRUCTURE



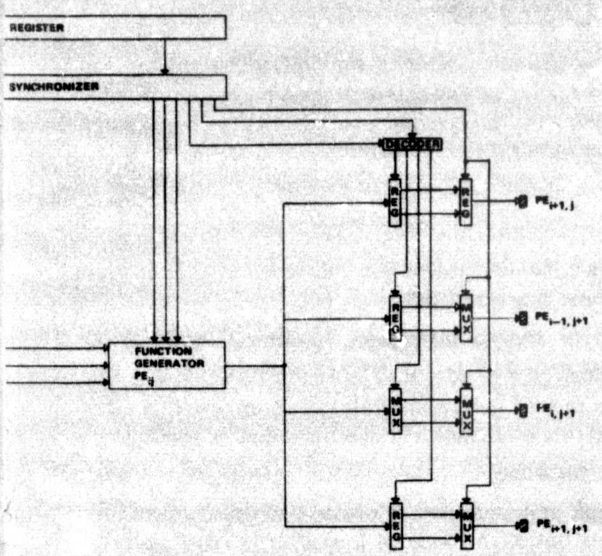
The matrix has separate data and instruction buses. These buses operate in a multiplex mode. The data bus structure is a hardwired unidirectional 16-wire system. The instruction bus transmits the necessary control signals which enable each processing element to

MECHANICAL PACKAGING



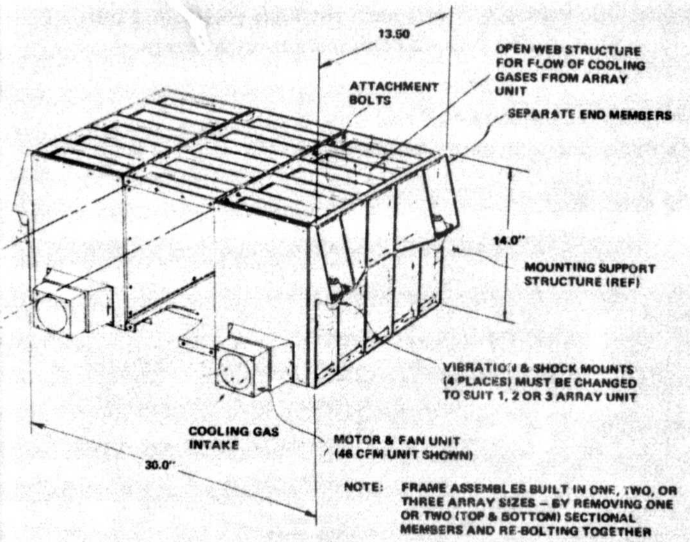
ARRAY UNIT

The OEDSF Unit has been designed to support missions in two areas of space shuttle environments: (a) within the cabin, pressurized area; (b) on the payload pallet, unpressurized area. To accommodate both environments, a circulating gas cooled packaging arrangement was studied and deemed best suited to both conditions. An alternate passive, conductive heat sink



- route up to three arguments
  - receive from four processing elements
    - transmit to four processing elements
      - perform a given operation

The 5 x 5 matrix requires that 25 instructions be transmitted every machine cycle. The microcode required to control the interprocessing and intraprocessing elements has been established at twentyfour bits.



module configuration was also studied. The OEDSF can be heat sunk to a cold plate as hot as 50^{o}C.

Present technology utilizing discrete logic integrated circuits requires approximately 170 chips per functional element of the OEDSF. It is anticipated that exploitation of emerging technologies (such as 64K memory chips) and fabrication techniques will enable each element to be accommodated on a single 9 x 10 inch board and that an entire OEDSF matrix including its data base and control system will consist of approximately 30 such boards. An LSI implementation would provide an entire matrix on a single board. The packaging concept enables up to 3 OEDSF matrices to interconnect mechanically and electrically.

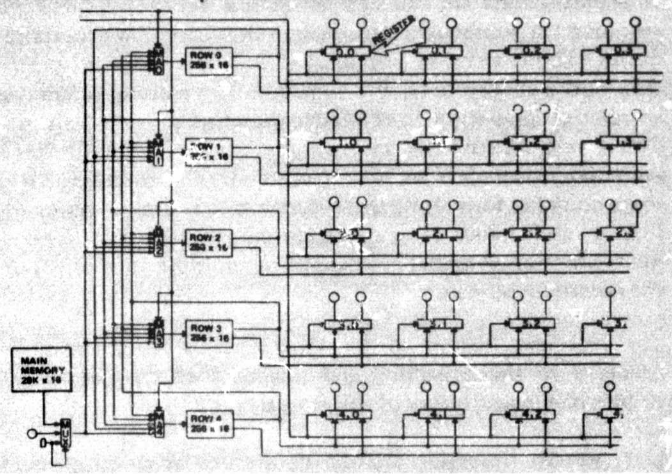
MEMORY STRUCTURE

The selected design for the memory structure is based on separate data base memory and program memory which are of identical architecture. The dual memory structure provides a cost-effective and high reliability approach. The sensor processing requires a data base which typically contains:

- Constants
  - Transfer Functions
    - Calculated Parameters

The volume and nature of the data base is dependent on the specific sensor and process utilized, thus the memory structure is modular. A data buffer providing the storage required to delay the primary and/or secondary sensor data is provided on each functional element and is discussed under the Input/Output section.

The memory structure is hierarchical and consists of a Central Library, Cache Memories (associated with each matrix row), and Scratch Pad Memories (associated with each Arithmetic element). This combination maximizes access speed and minimizes hardware requirements.

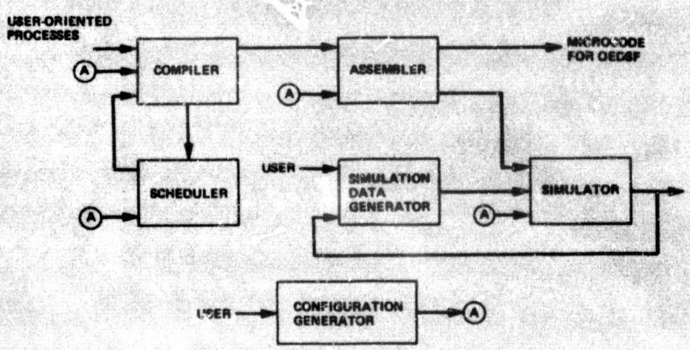


INDEX GENERATING PROGRAM

The OEDSF can be programmed manually. This is an easy task in the case of a single sensor. When many sensors are competing for the use of the OEDSF's elements, the scheduling of these elements becomes a tedious task which is ideally suited for computers.

The OEDSF concept envisions a computer program, the Index Generating Program (IGP), which generates, off line, the microcode required to control the OEDSF in a cost- and schedule-effective manner.

This program resides in a TBD host computer of the PDP 11/70 class. It accepts the processing requirements of the complement of instruments comprising a given payload in a user oriented language and produces the microcode directly useable by the OEDSF controller.



EFFECTIVENESS OF THE OEDSF

The OEDSF realizes its benefits by exploiting its unique location in both a spatial and temporal sense. This exploitation is enhanced by the judicious choice of the processes which it performs, and by its architecture. The benefits realized are in both the operational and the cost domains.

For each of the boundary sensors, the OEDSF produces data or information ready for extractive processing or user modeling. In each case, the processing requirements on the ground are significantly reduced or eliminated.

OPERATIONAL ADVANTAGES

The OEDSF operates in real time. The output signals from the experiments are fed to the OEDSF as the experiments generate them. All ancillary data are available to the OEDSF coincident with their generation. Ancillary data are all data used to operate upon or characterize the experiment data. They include:

1. Housekeeping data
2. Guidance, Navigation, and Control (GNC) data
3. Auxiliary information.

If ancillary data are not utilized in real time, they must be recorded for subsequent processing. The recording process requires a formatting and a time-tag operation of both the sensor data and ancillary data; the subsequent processing requires a correlation operation to re-match the ancillary data with the sensor data. Alternately, the ancillary data may be multiplexed with the sensor data so that re-correlation is obviated, but a more complex formatting and reformatting process is required; further, each sensor must duplicate the recording of this common information with a corresponding multiplicative effect on the recording burden.

The real-time feature of the OEDSF provides an adaptive property to the collecting and recording of data. Some examples of the utilization of this property are:

1. Inhibit collection of bad data (such as cloud covered targets, or when SNR is inadequate).
2. Select signals to be processed (or recorded) from multi-signal or multi-channel instruments based on criteria which may be dependent on the scene characteristics or the signal characteristics.
3. Establish or change instrument operating mode based on characteristics of data or ambient conditions.
4. Vary the rate of correction data collection based on the measured rate of change of the error-inducing agent.
5. Point instruments.
6. Quick look at experiment results to determine operation quality or optimize mode of instrument. This also provides an interactive operation with the onboard crew.

Processing the data prior to recording or transmission usually effects significant reductions in recorded volume. The ancillary data which need no longer be recorded often exceeds the volume of data produced by the low frequency (up to several kilobits per second) sensors.

As the prime data gets converted to information, its bulk greatly diminishes. For example, the IRS raw data is collected in 12 bit words for each grid point in 17 channels, a total of 17,136 bits for each group of 3 subgrids (28 points per subgrid). The output of the OEDSF is 20 temperature values and 20 mixing ratio values at 7 bits each for each group of 3 subgrids, for a total of 280 bits – a compression ratio greater than 60 to 1.

The most significant aspect of real-time processing is that the data is ready for the experimenter when the shuttle lands. The pre-processing through a central facility with its attendant queue is eliminated.

	DATA IMMEDIATELY AVAILABLE ON HDDT	DATA COMPRESSION RATIO	ANCILLARY DATA	GROUND PROCESSING ELIMINATED	GROUND PROCESSING ADDED	CONVENTIONAL APPROACH TIME
ATS	CORRECTED DIGITAL IMAGERY WITH LAT AND LON	NONE	ELIMINATED	CALIBRATION RADIOMETRIC AND GEOMETRIC CORRECTION	NONE	6 TIMES REAL TIME
IRS	RAW TEMPERATURE AND MIXING RATIO PROFILES WITH LAT AND LON PER GRID	60:1	ELIMINATED	CALIBRATION CALCULATION OF TEMP AND MIXING RATIO	FLAG CHECK	1/8 REAL TIME WITH 24 HOURS DELAY
RADSCAT	σ_o AND T_A WITH LAT AND LON	90:1	ELIMINATED	CALIBRATION CALCULATION OF σ_o AND T_A	NONE	35 TIMES REAL TIME
CIMATS	SPECIE CONCENTRATION WITH LAT, LON, AND ALTITUDE	20:1	ELIMINATED	ALL	NONE	TBD

COST ADVANTAGES

The cost-effectiveness of the OEDSF was established by the comparison of the costs for equivalent processing of the data of the boundary sensors as performed by traditional (all ground) methods and as performed by the OEDSF.

All costs given are in constant 1976 dollars. The costs of the conventional processing systems for the boundary sensors was determined. These costs include design and development, hardware, and operation. The OEDSF has been specifically designed to be cost-effective with frequently changing configurations of sensors flying infrequently, whereas operational systems, notably the ATS ground system, have been designed to be cost-effective with operational invariant payloads. In such a case, cost comparisons would appear to require adjustments; however, it is clear that other systems, such as the RADSCAT, were specifically designed for a limited number of experimental flights and that the basis for the cost of their ground system compares identically with those of the OEDSF and are, further, comparable with operational systems costs when normalized for data rate and processing complexity. In other words, ground systems designed for limited numbers of experimental missions appear to cost approximately the same as those designed for operational use. The major difference, which has been reflected in the cost comparisons, is that the general purpose hardware, i.e., computers, can be reallocated to other uses in the case of experimental programs.

Integration schedules and support and spares requirements result in an overall program need for 9 OEDSF's. The cost of design, development, production and test of these 9 units is $5.7 million.

The cost of the OEDSF assigned to each of the boundary sensors is based on the fraction of the OEDSF it uses. It is further assumed that in most cases the OEDSF is only used at 50% of its capability because of programming inefficiencies.

The utilization factor has a significant effect on the cost of processing a sensor onboard. If the OEDSF is not fully utilized (less than 20 composite sensors), the flight cost of each sensor increases proportionately.

COST OF USING THE OEDSF

$$C_T = \frac{U}{E}\left[NC_U + C_f\right] + C_i + C_s + C_p$$

WHERE,

C_T = COST PER SPECIFIED SENSOR PER MISSION

U = PORTION OF OEDSF UTILIZED BY SENSOR - DERIVED FOR EACH SENSOR

E = EFFICIENCY OF UTILIZATION OF THE OEDSF - FUNCTION OF NUMBER OF SENSORS

N = NUMBER OF OEDSF TO SUPPORT MISSION = 1 (UNIT ONBOARD) + 2/7 (BACKUP) ≈ 1.3

C_U = COST OF OEDSF HARDWARE = AMORTIZED COST OF OEDSF + REFURBISHMENT
ASSUME 25 MISSIONS PER YEAR X 10 YEARS = $\frac{250}{9}$ = 28 FLIGHTS/OEDSF

ASSUME 4% of HARDWARE COST PER FLIGHT REFURBISHMENT COSTS
= $\frac{636K}{28}$ + 0.04 x 636K = $48.2K

C_f = FLIGHT COST = $59.3K

C_i = INTEGRATION COST = $15,600 + COST OF SIMULATOR EQUIPMENT

C_s = AMORTIZED COST OF IGP = $\frac{\$950K}{842 \text{ SENSORS}}$ = $1.1K

C_p = COST OF PROGRAMMING SENSOR WITH IGP BEFORE EACH FLIGHT
= $0.5K

COST OF CONVENTIONAL SYSTEM

DEDICATED FACILITIES (SINGLE OR FINITE GROUP)

$$C_T = (C_H + C_{CS})\frac{U}{F} + \frac{C_{DS}}{F} + C_0 U$$

WHERE

C_T = COST OF CONVENTIONAL SYSTEM PER MISSION PER SPECIFIC SENSOR

C_H = HARDWARE COST

C_{CS} = COMMON SOFTWARE

U = PERCENTAGE SHARE OF FACILITY USAGE

C_{DS} = DEDICATED SOFTWARE

C_0 = OPERATIONAL COST OF FACILITY

F = NUMBER OF MISSIONS FLOWN BY SPECIFIC SENSOR

COMMON SHARED FACILITIES (GENERAL PURPOSE COMPUTERS)

$$C_T = AC_A + \frac{C_{DS}}{F}$$

WHERE

C_A IS COST PER UNIT TIME FOR USE

A IS TIME REQUIRED TO PROCESS MISSION DATA

INSTRUMENT	EQUIVALENT NUMBER OF MISSIONS (OVER 10 YEARS)	CONVENTIONAL SYSTEM COST PER MISSION $K	OEDSF COST PER MISSION		
			SENSORS 20	SENSORS 10	SENSORS 5
ATS	260	24.0	123.6	123.6	123.6
	130	44.3	123.8	123.8	123.8
	20	268.0	125.5	125.5	125.5
	2	2648	163.9	163.9	163.9
IRS	260	14.8	2.6	3.7	5.8
	130	17.0	2.7	3.8	5.9
	20	42.0	3.4	4.5	6.6
	2	307.5	18.4	19.5	21.6
RADSCAT	260	79.4	2.0	2.3	3.1
	130	83.3	2.1	2.4	3.2
	20	125.6	2.8	3.1	3.9
	2	575.6	17.7	18.0	18.8
CIMATS	260	45	2.2	2.9	3.3
	130	48	2.3	3.0	3.4
	20	81	3.0	3.7	4.1
	2	432	17.9	18.6	20.0

BENEFITS AS A FUNCTION OF THE USER

Onboard processing is not equally applicable to all experimenters. We have found many experimenters anxious to exploit the benefits of onboard processing described above, and other experimenters who were strongly opposed to any reduction of their data. We have attempted to define the various users and their associated potential as onboard processing beneficiaries.

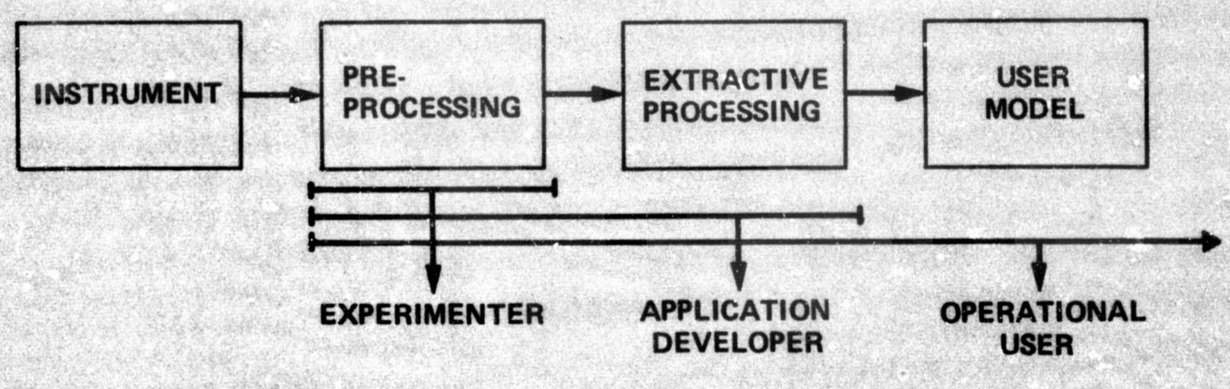
The users of instrument data can be placed in three categories defined by their utilization of the data. Each category has its own set of problems, needs, and desires.

The Instrument Developer is primarily interested in the basic electro-optical response of his sensor and therefore can evaluate its performance by assessing the data in its raw or nearly raw form. This raw data, when preprocessed such as by reformatting or the insertion of calibration factors, will enable him to directly determine his instrument's performance. In general, the number of instrument developers is relatively small and their use of the data is often very similar. This situation of a few users, coupled with similar processing requirements, is ideal for the application of standardized processing such as onboard processing. Further, the volumes of data which would be investigated and analyzed in order to evaluate the sensor's performance is generally quite small. A few well-chosen measurements compared with well-instrumented or calibrated test observables will provide the Instrument Developer with sufficient knowledge to determine the performance of his sensor. Often, based on this data, the sensor's characteristics are modified and the instrument is again exercised against the test observations.

The Application Developer is concerned with determining the utility of the remotely sensed data to various applications. The satisfaction of this need consists primarily of applying and testing various extractive processing techniques and user models. The basic data input to this process is generally well established and almost always preprocessed to a nominal extent. In the area of alternative extractive processing and user model techniques, the Application Developer requires flexibility to exercise different techniques on the data over a relatively wide range of data characteristics. This situation is amenable to onboard processing in two ways. First, the degree of preprocessing is generally well understood and standardized, thus lending itself to a routine preprocessing function; and, second, the various extractive techniques can often be easily implemented at least in a low volume situation with a general purpose onboard processing system.

The Operational User is characterized as a resource manager or other similar application discipline who has a management function to perform and will use remotely sensed data as one of several information sources upon which to base his decisions. Inasmuch as the usage of this data input is well understood and relatively standardized, it lends itself well to consistent and routine processing, both preprocessing and extractive processing and some aspects of the user model. For any particular application, the number of Operational Users is relatively small and the processing required of the input data is relatively invariable.

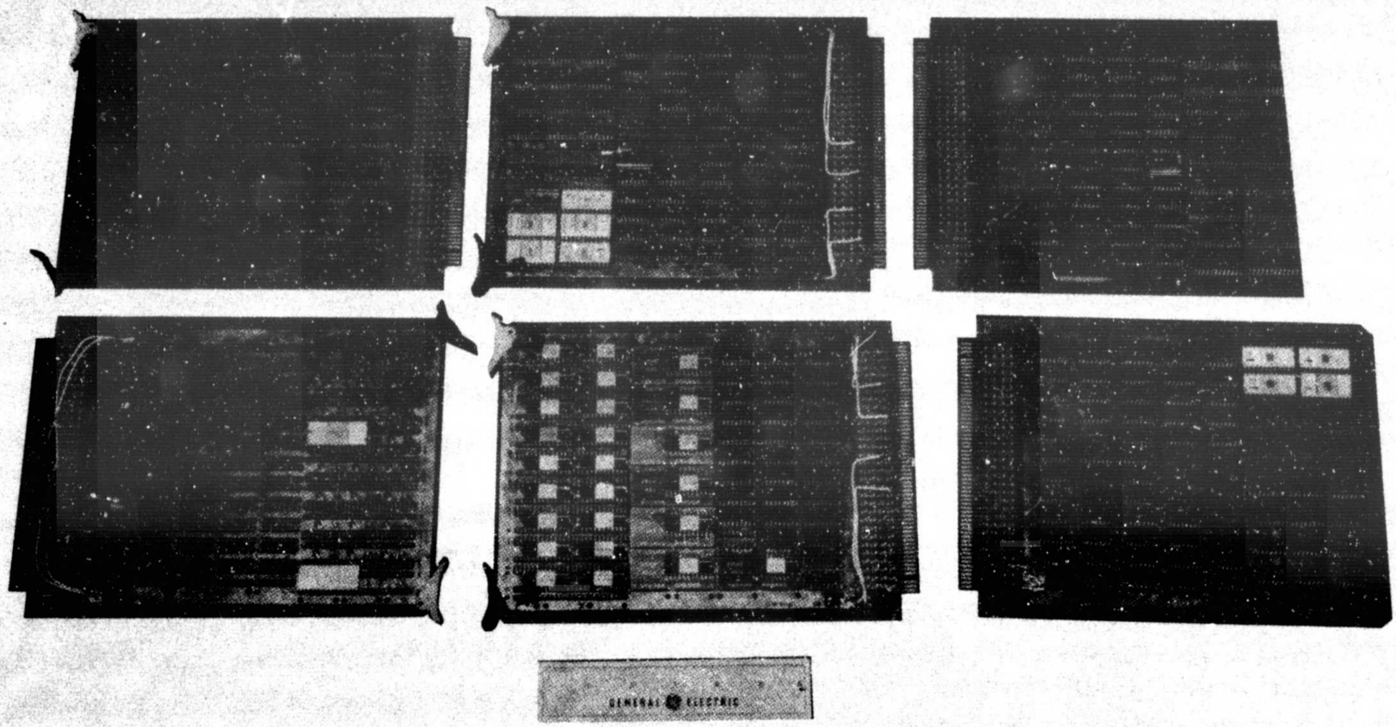
Onboard processing has the flexibility and capability to serve each of these users and meet their requirements.



Range of Processing Needs

BREADBOARDING ACTIVITIES

During the performance of this study, General Electric conducted an Independent Research and Development program which produced detail designs and breadboards of the major components of the OEDSF. Results of this activity were fed back to the OEDSF study to modify or change the original conceptual designs as found necessary.



FOR ADDITIONAL INFORMATION CONTACT:

Mr. Robert L. Giesecke
Technical Monitor
National Aeronautics and Space Admin.
Johnson Space Center, Code ED5
Houston, Texas 77058

Mr. Georges G. Frippel
Program Manager
General Electric Co.
Valley Forge Space Center
Philadelphia, Pa. 19101